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Optimum plot size, shape and number of replications for field experiment on wheat (*Triticum aestivum* L.)

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ABSTRACT

Field experiment on wheat crop was conducted during *rabi*-2012 at Junagadh. The crop yield data of 1296 basic units (Basic unit = 0.90 m x 1.00 m) were recorded and analyzed to work out optimum size, shape and number of replications of the plot using Fairfield Smith's, maximum curvature methods and Cochran & Cox equation respectively. The per unit decrease in C.V.% for different plot sizes estimated from the differences between C.V.% of consecutive points indicated that the effective decrease in C.V.% due to increase in plot size was up to 12 units sized plot. The graphical presentation of C.V.% also revealed similar trend, therefore, 12 units size i.e. 10.80 sq. m. size could be considered as optimum plot size. The Smith's model was considered as a measure of correlation between adjacent units with "b" = 0 indicating perfect correlation between adjacent plots. The medium range of "b" obtained in this study indicated the use of smaller plots in field experiments. The equation obtained was, $Y = 11.08\,X^{-0.0384}$. The coefficient of determination (R^2) between plot size and C.V.% was computed as 0.36. The results revealed that the smaller plots with fairly large number of replications were observed to achieve 5 per cent accuracy in any of the block size. The increase in plot size from 0.90 m^2 to 10.80 m^2 resulted in reduction of 14 to 2 or 3 to 2 replications, respectively, to obtain the same precision. For controlling soil variation, a block of 3 x 3 plots was required with minimum 2 replications to a chive 5 per cent accuracy for field experiments in wheat crop in Saurashtra region.

Key words : Optimum plot size, replication, wheat.

Each experimental material has inherent variation, which could be accessed through uniformity trial. Uniformity trial helps in proper selection in size, shape and number of replications for field experiments. Field experimentation is one of the powerful tools in research for agricultural science. The experiments were conducted on various crops in irrigation condition at saurashtra region. Wheat is a major cereal growing crop of this region, relatively high variability (>50 %) in this crop.

MATERIALS AND METHODS

Uniformity trial was conducted during *Rabi* - 2012 at Wheat Research Station, JAU, Junagadh. The crop was sown in east to west direction with inter row spacing of 22.5 cm. The crop was harvested in continuous basic unit, each of 0.90 m x 1.00 m consisting of a four rows of 1.00 m length. Fairfield Smith's (1938) variance law and maximum curvature Federer (1955) methods were used for determining optimum plot size and shape on the basis of uniformity trial. Smith's law is as follows,

$$V_x = \frac{V_1}{X^b}$$

Where :

V_x = the variance of mean per plot of X units,
X = the number of basic units in a plot,
V_1 = the variance of mean per plot of one unit,
b = the regression coefficient.

This equation can be written as,

$$\log V_x = \log V_1 - b \log X$$

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Maximum Curvature method Federer (1955). A curve is plotted by taking the plot size (in terms of basic units) on the X–axis and the C. V. values on the Y- axis of a graph (Fig. 1). The point at which the curve taken a turn, that is the point of maximum curvature. The value corresponding to the point of maximum curvature will be the optimum plot size. Coefficient of variation (C.V.%) per unit area was estimated for various sized plots as under.

$$\text{C.V.\%} = \frac{\text{Standard deviation per unit}}{\text{General mean}} \times 100$$

The number of replications required varies with the number of treatments, variation of the character measured, the confidence probability of significant difference and assurance of detecting the difference. The Statisticians Hatheway, Cochran & Cox (1957) equation for estimating the minimum detectable difference between two treatments as a per cent of the mean can be estimated using following relation.

$$d^2 = \frac{2\,(t_1 + t_2)^2\,(C.\,V.)^2}{r\,x^b}$$

Where,

- d = true difference which can be detected at a specified level of significance
- t_1 = significant value of t in the test of significance.
- t_2 = table value of t corresponding to 2(1-p), where p is the probability of obtaining a significant result.
- r = required replications number
- c.v. = coefficient of variation per basic unit area, expressed as a percent of the mean, for the plot size and shape used
- x = number of basic units in the combined plot size
- b = soil heterogeneity index (linear regression coefficient)

RESULTS AND DISCUSSION

The comparisons were made among different sizes and shape of plots using coefficient of variation per units area, C. V. % estimated from Wheat yield.The results are presented in Table-1 indicate that maximum C.V.% (24.42) was observed in the smallest sized plot *i.e.,* one unit (0.90 sq.m.). C.V. % decreased with the increase in plot size up to 72 units size (5.07%). The decrease in C.V.% was not proportional when the plot size is increased beyond 9 units plot. Therefore 9 units size could be taken as point of maximum curvature (Fig. 1). Beyond this point, the decrease in C. V. % was not proportional to the amount of land used. The optimum plot size is one just beyond the point of maximum curvature. Therefore 12 units sized plot was considered as optimum plot size Fairfield Smith's (1938) and Federer (1955). The graphical presentation of C.V. % against plot size (Fig.1) also revealed similar trend. The rate of reduction in C.V.% was more with the increase in length of the plot than that with the increase in width (*i.e.,* number of rows) of plot (Table 1).

The per unit decrease in C.V.% (Table 1) for different plot sizes estimated from the differences between C.V.% of consecutive points indicated that the effective decrease in C.V.% due to increase in plot size was up to 12 units sized plot. The graphical presentation of C.V.% (Fig. 1) also revealed similar trend, therefore, 12 units size *i.e.,* 10.80 sq. m. size could be considered as optimum plot size. These results are in agreement with those reported by Khokhar *et al.,* (1997) in brinjal, Naliyadara *et al.,* (2010) in tomato, Prajapati *et al.,* in mustard (2013) and Naliyadara *et* al., in groundnut (2013)

Among all combinations of 12 units plot (6 x 2), a plot of 6 m. x 1.8 m. had minimum C.V. % per units area (8.06 %) therefore, it can be concluded that a plot of 6 m. x 2.0 m. (8 rows each of 6.00 meter length) could be taken as optimum plot size.

Keeping in view the above results as well as practical difficulties for caring out the agricultural operations, the plot of 4 x 3 having dimensions 4.0 m. x 2.7 m. *i.e.,* 12 rows each of 4.0 meter length could be used instead of plot having dimension of 6.0 m x 2.0 m. This shape has little higher C.V.% (8.16) as compare to 12 units plot (6 x 2) a plot of 6.0 m X 1.80 m had C.V.% per unit area (8.06).

The Smith's Law was considered as a measure of correlation between adjacent units with "b" = 0 indicate perfect correlation and "b" = 1 indicate heterogeneity between adjacent plots. The range of "b" 0.860 to 0.724 was obtained in this study, It was indicated the use of smaller plots in field experiments. The equation obtained was as under.

$$Y = 11.08X^{-0.0384}$$

The coefficient of determination (R^2) between plot size and C.V.% was computed as 0.40. The trend of C.

Table 1 Coefficient of variation (c.v.) in percentage, Different in c.v. and Soil heterogeneity index for different sizes and shapes of plots for Wheat yield, *rabi*-2012-13.

Plot Size	Shape in Basic Unit (L x W)	Variance Between the Plot V(x)	Variance per unit area Vx	C.V. % Plot	C.V. % Mean	Difference in C.V.%	Per unit decrease in C.V. %	Soil heterogeneity (b)
1	1x1	12048.65	12048.65	24.42	24.42	0.00	0.00	0.00
2	2x1	24112.64	6028.16	17.27	18.10	6.32	6.32	0.860
	1x2	28990.67	7247.67	18.93				
3	3x1	38188.00	4243.11	14.49	15.51	2.59	3.73	0.822
	1x3	49684.12	5520.46	16.52				
4	4x1	50451.36	3153.21	12.49	13.76	1.75	0.84	0.821
	2x2	57612.45	3600.78	13.34				
	1x4	77118.22	4819.89	15.44				
6	6x1	80264.00	2229.56	10.50	11.75	2.01	-0.26	0.811
	3x2	91518.68	2542.19	11.21				
	2x3	101067.10	2807.42	11.78				
	1x6	132744.00	3687.33	13.50				
8	4x2	121142.5	1892.85	9.67	10.32	1.43	0.58	0.826
	2x4	155473.4	2429.27	10.96				
9	9x1	132539.0	1636.28	8.99	10.30	0.02	1.41	0.779
	3x3	161349.0	1991.96	9.92				
	1x9	235159.0	2903.20	11.98				
12	12x1	158641.8	1101.68	7.38	9.08	1.22	-1.20	0.787
	6x2	189285.3	1314.48	8.06				
	4x3	194199.1	1348.61	8.16				
	3x4	259139.6	1799.58	9.43				
	2x6	279836.5	1943.31	9.80				
	1x12	392231.1	2723.83	11.60				
16	4x4	336352.4	1313.88	8.06	8.06	1.02	0.20	0.799
18	18x1	271516.0	838.01	6.43	7.95	0.11	0.91	0.768
	9x2	321104.0	991.06	7.00				
	6x3	323144.0	997.36	7.02				
	3x6	480136.0	1481.90	8.56				
	2x9	496412.0	1532.14	8.70				
	1x18	650324.0	2007.17	9.96				
24	12x2	368931.6	640.51	5.62	7.05	0.90	-079	0.775
	6x4	540174.3	937.80	6.81				
	4x6	627057.8	1088.64	7.33				
	2x12	827000.9	1435.77	8.42				
27	9x3	536940.0	736.54	6.03	6.80	0.25	0.65	0.772
	3x9	843876.0	1157.58	7.56				

36	36x1	540192.0	416.81	4.54				
	18x2	711536.0	549.02	5.21				
	12x3	579136.0	446.86	4.70				
	9x4	930128.0	717.69	5.95				
	6x6	1025792.0	791.51	6.25	6.32	0.48	-0.23	0.743
	4x9	1189520.0	917.84	6.73				
	3x12	1547184.0	1193.82	7.68				
	2x18	1485632.0	1146.32	7.53				
	1x36	1783872.0	1376.45	8.25				
48	12x4	990919.1	430.09	4.61	5.72	0.60	-0.12	0.740
	4x12	2172473.0	942.91	6.83				
54	18x3	1078776.0	369.95	4.27				
	9x6	1899648.0	651.46	5.67	5.58	0.14	0.46	0.734
	6x9	2082132.0	714.04	5.94				
	3x18	2445588.0	838.68	6.44				
72	36x2	1215488.0	234.47	3.40				
	18x4	1993024.0	384.46	4.36				
	12x6	2000448.0	385.89	4.36	5.07	0.51	-0.37	0.724
	6x12	3538944.0	682.67	5.81				
	4x18	3691200.0	712.04	5.93				
	2x36	4482752.0	864.73	6.54				

Fig. 1 : Average Coefficient of variation for different sized plot in Wheat

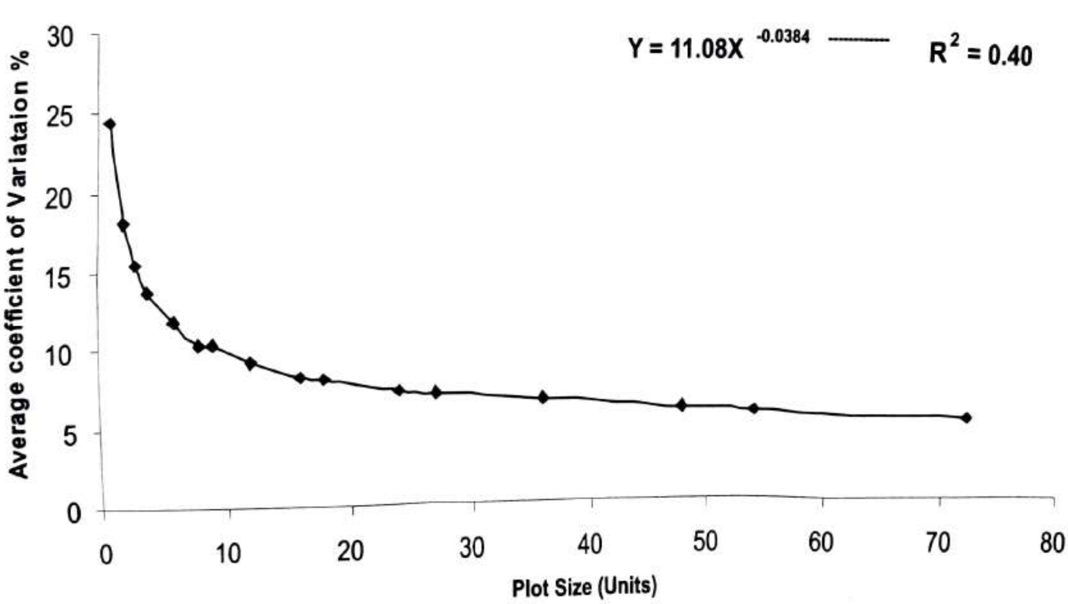

Table 2. Effective number of replications for 5 % standard error and total area required per treatment with different plot sizes.

Plot size			Number of replications								Total area required per treatment (m^2)							
			Block Shape								Block Shape							
Length (Unit)	Width (Unit)	Area (m^2)	1x2	1x3	1x4	1x6	2x4	3x3	3x4	4x4	1x2	1x3	1x4	1x6	2x4	3x3	3x4	4x4
1	1	0.90	14	10	8	6	5	3	3	2	12.60	9.00	7.20	5.40	4.50	2.70	2.70	1.80
1	2	1.80	8	6	5	3	3	3	3	2	14.40	10.80	9.00	5.40	5.40	5.40	5.40	3.60
1	3	2.70	6	3	3	3	3	3	3	2	16.20	8.10	8.10	8.10	8.10	8.10	8.10	5.40
1	4	3.60	5	3	3	3	3	3	2	2	18.00	10.80	10.80	10.80	10.80	10.80	7.20	7.20
1	6	5.40	3	3	3	2	2	2	2	2	16.20	16.20	16.20	10.80	10.80	10.80	10.80	10.80
2	1	1.80	8	6	5	3	3	3	3	2	14.40	10.80	9.00	5.40	5.40	5.40	5.40	3.60
2	2	3.60	5	3	3	2	2	2	2	2	18.00	10.80	10.80	7.20	7.20	7.20	7.20	7.20
2	3	5.40	3	3	2	2	2	2	2	2	16.20	16.20	10.80	10.80	10.80	10.80	10.80	10.80
2	4	7.20	3	3	2	2	2	2	2	2	21.60	21.60	14.40	14.40	14.40	14.40	14.40	14.40
2	6	10.80	3	3	2	2	2	2	2	2	32.40	32.40	21.60	21.60	21.60	21.60	21.60	21.60

V.% was expressed in equation form. The equation derived to show the relation between C.V. % and plot size, X using original data as well as log transformed data are as under.

1) *Original data :*

$$Y = \frac{a}{X^b}$$

$$C.V. = 11.08 - 0.0384X \quad \ldots\ldots\ldots\ldots \quad (R^2 = 0.40)$$

2) Log transformed data

$$\text{Log C. V.} = \text{Log a} \pm \text{b Log X}$$
$$Y = 1.352 - 0.292\ X \quad \ldots\ldots\ldots\ldots \quad (R^2 = 0.99)$$

The reduction in experimental error for treatment comparison can be achieved by (i) increasing number of replications and (ii) taking large plot (Agarwal *et al.*, 1967). Two criteria are complementary for a fixed experimental area. Hence, the effective number of replication and total area required per treatment were worked out for various plot sizes. The results (Table 2) revealed that the smaller plots with fairly large number of replications were observed to achieve 5 per cent accuracy in any of the block size. The increase in plot size from 0.90 m^2 to 10.80 m^2 resulted in reduction of 14 to 2 or 3 to 2 replications, respectively, to obtain the same precision. For controlling soil variation, a block of 3 x 3 plots was required with minimum 2 replications to a chive 5 per cent accuracy for field experiments in wheat crop in Saurashtra region. Similar results were reported by Saxena *et* al.,(1972) in oat grown for fodder, Thomas *et al.*,(1985) in brinjal, Patil *et al.*,(1987) in Indian mustard and Prajapati *et al.*,(2013) in mustard.

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